

Study Update: Dam Removal, Sediment Transport, and Potential for Oxygen Demand in the Klamath River

Water Quality Sub-Team Workshop
October 5, 2010

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Background

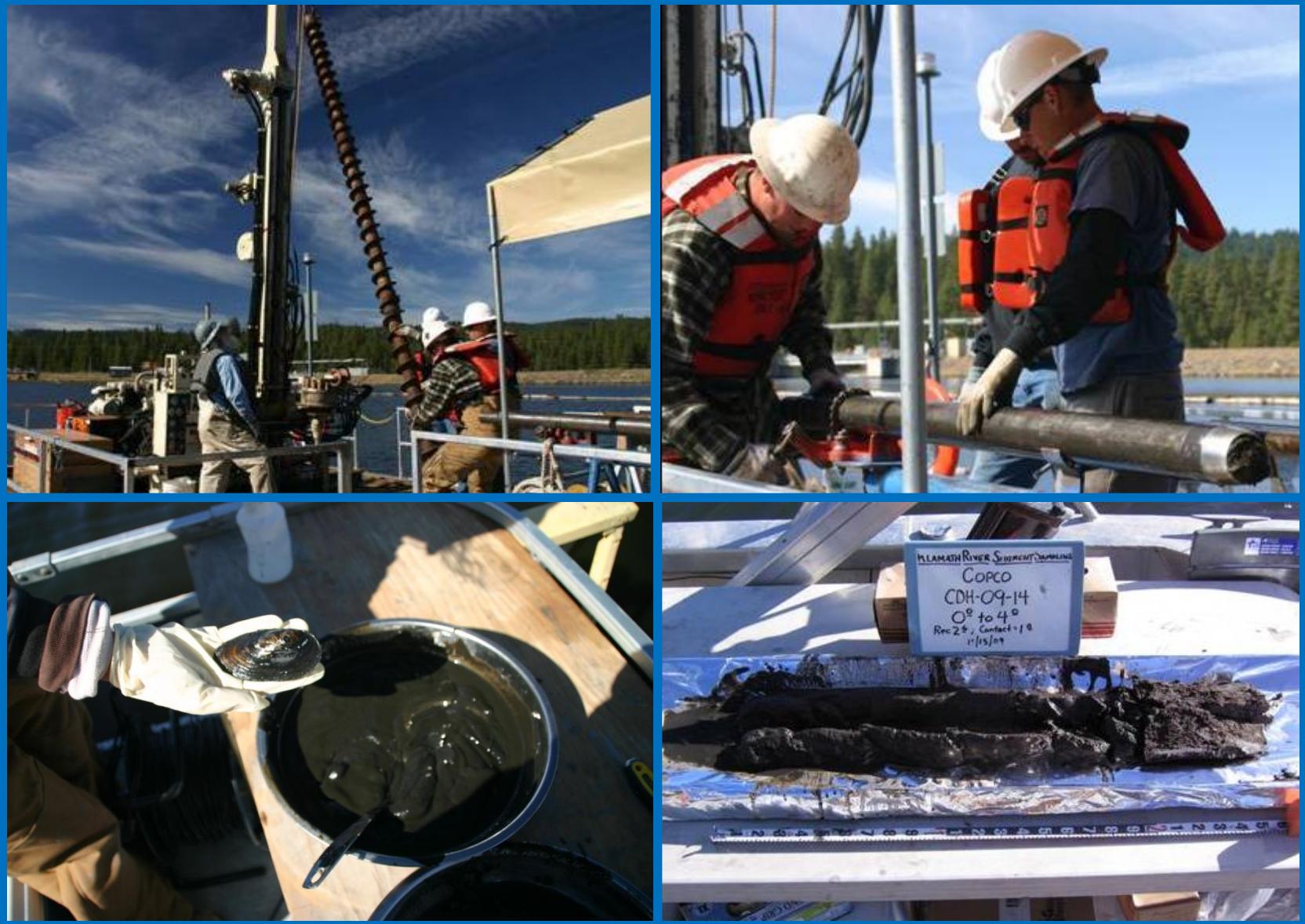
- Secretarial Determination/NEPA Process Effects Analysis for Proposed Action (i.e., Dam Removal)
- *Purpose:* To address the question What is the potential of total suspended sediments (TSS) to influence downstream water quality, and in particular dissolved oxygen (DO), in space and time in the Klamath River downstream of the Project Reach?

Approach

- 2-phase sampling (2009-2010)
- Laboratory testing (2009-2010)
- Data analysis (2010)
- BOD-IOD spreadsheet model development (2010)



Phase 1: Preliminary Sampling of Sediments from Reservoir Cores (Fall 2009)



KLAMATH SECRETARIAL DETERMINATION WATER QUALITY WORKSHOP

Photos by USBR Staff: Stuart Angerer

PRELIMINARY DATA SUBJECT TO REVISION

Phase 1: Preliminary Sampling and Analysis

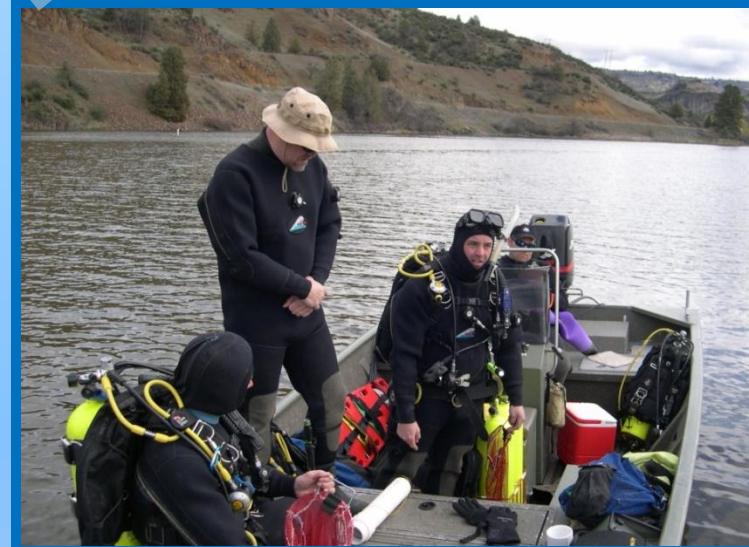
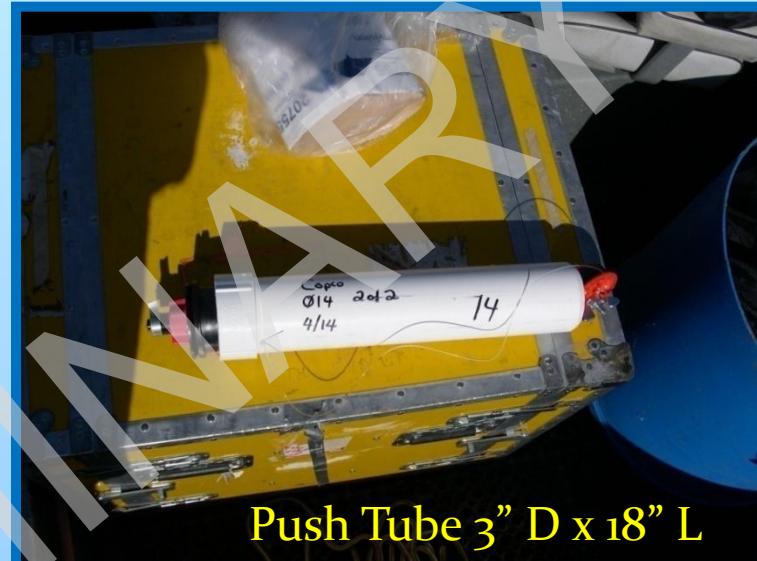
Fall 2009

- Contract lab performed DO depletion tests with sediment sub-samples (BOD₅, CBOD₅, BOD₃₀)
- Source water BOD
- Iron Gate and Copco 1 reservoir thalweg + non-thalweg samples (n=14 + QC)
- Different sample mass (0.5 to 8 g) in 300 mL BOD bottle
- Temps: 4 and 20 °C
- Mixing: 3X/day inversions
- Phase 1: Exposure of sediment samples to air may have allowed oxidation prior to laboratory analysis. Phase 1 results may be biased low.
- Phase 2: Refinement of sampling methodology and laboratory procedures to prevent potential oxidation prior to the experiment to target “**Immediate Oxygen Demand**” or IOD (e.g., sulfides and other reduced minerals)

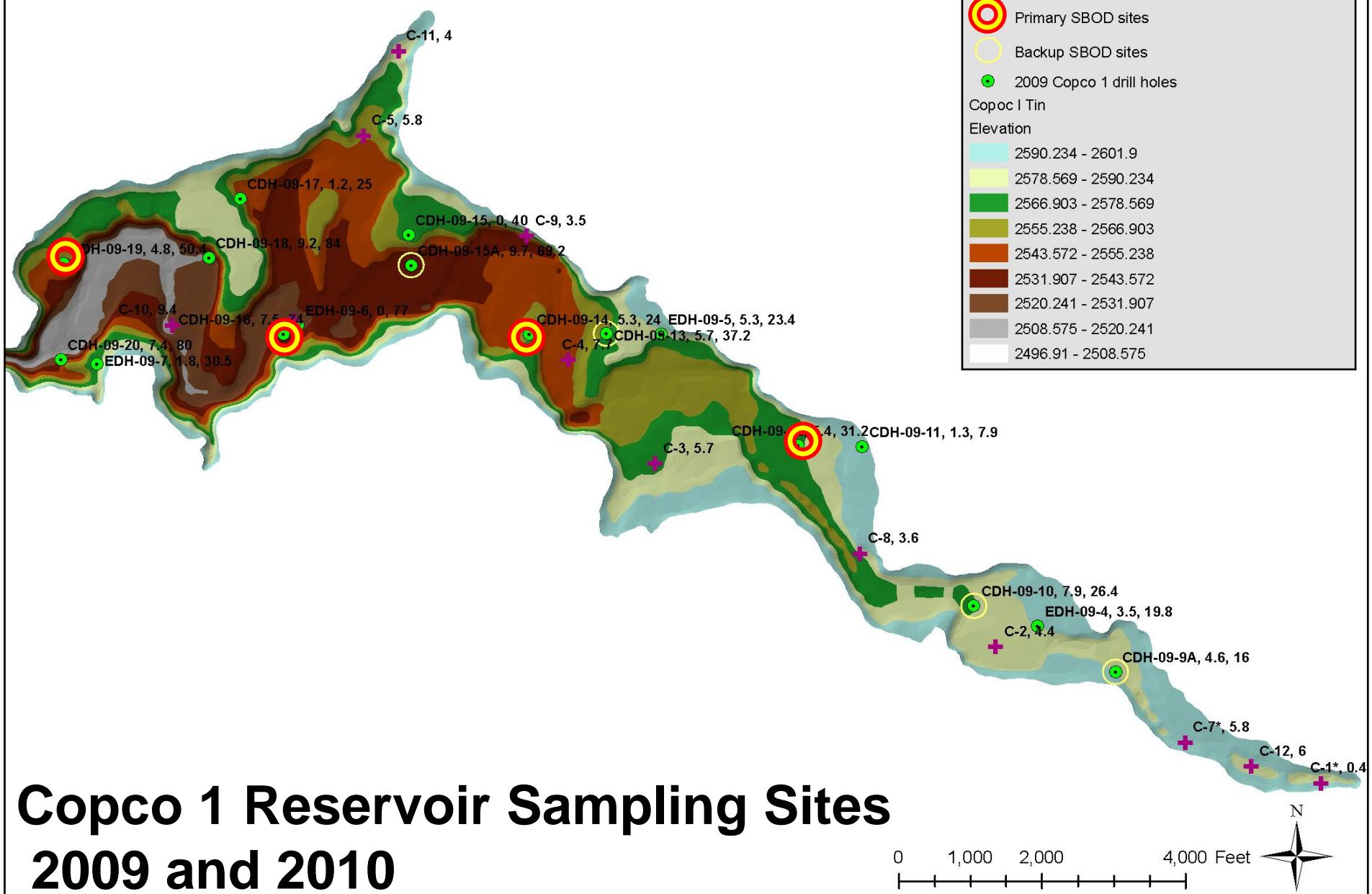
Phase 2: Follow-up Sampling for IOD

April 2010

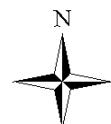
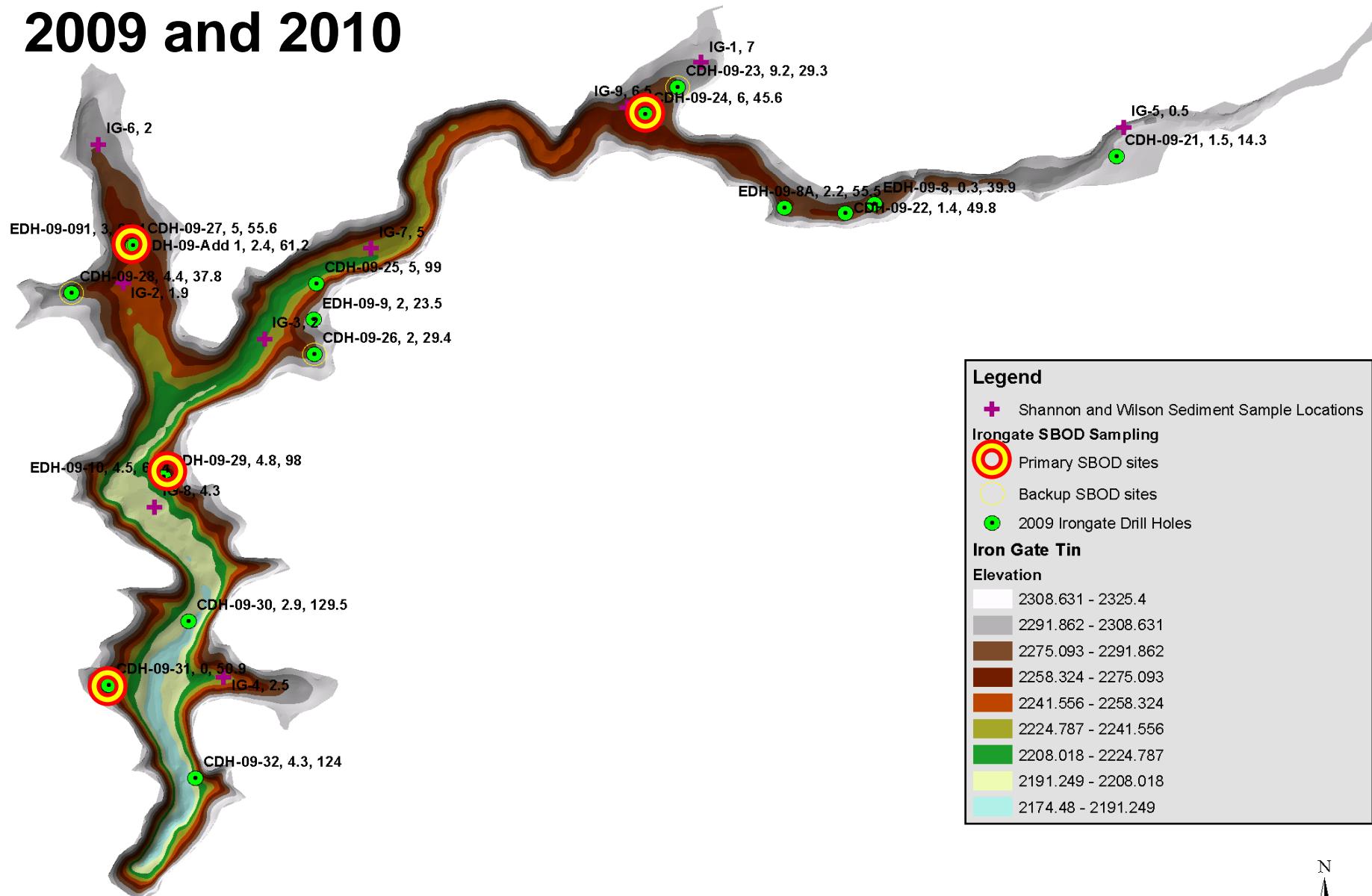
- Goal: Refined sample handling to prevent oxidation of sediments by water or air to evaluate the magnitude of IOD that may have been missed during fall 2009 sampling
- Capitalize on diver inspections of dam structures in April 2010 to collect additional samples
- New sample methodology: Divers with 3" push tubes capped at depth to prevent oxidation
- 4 composite samples (plus 4 backups) at each of Iron Gate and Copco 1 Reservoirs



KLAMATH SECRETARIAL DETERMINATION WATER QUALITY WORKSHOP
PRELIMINARY DATA SUBJECT TO REVISION



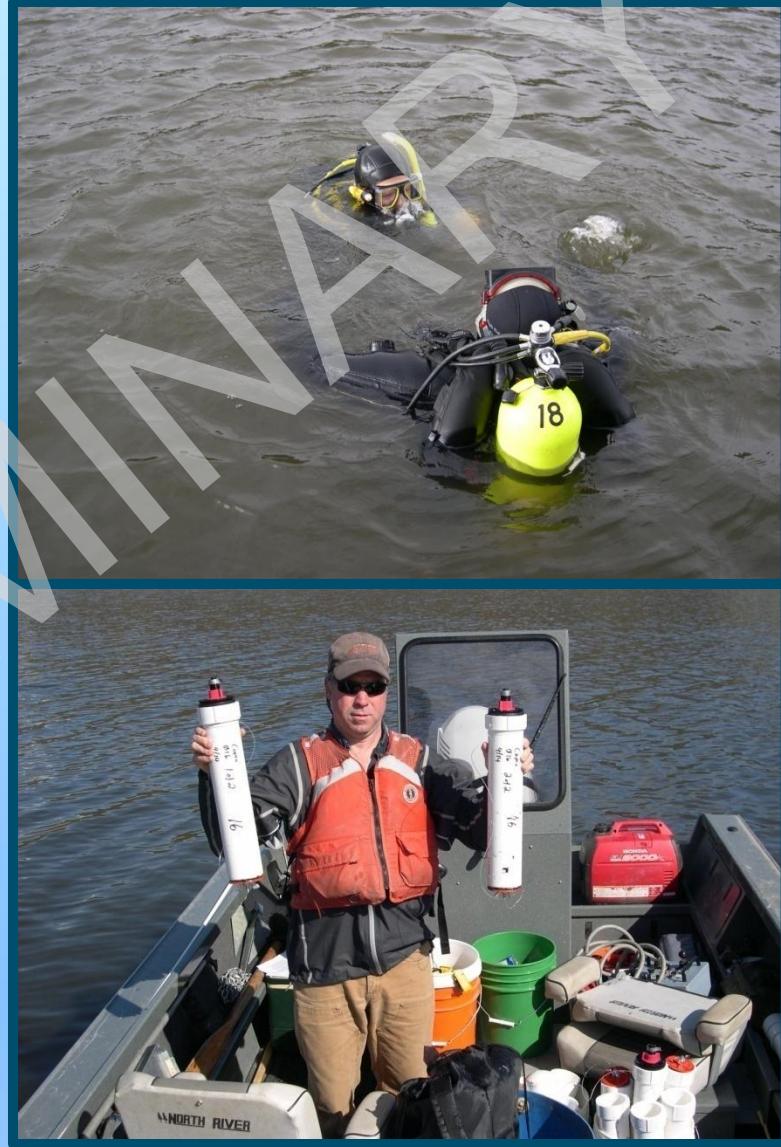
Iron Gate Reservoir Sampling Sites 2009 and 2010



Sample Handling

2009-2010

- Samples iced upright following collection and while in transit to the laboratory
- Source water collected to support laboratory experiments
- Laboratory processed samples within two days of collection



Laboratory DO Depletion Tests

Stored Samples (~ 4 C)



“Core each Core” w/2” poly tube outside of glove box with in 48 hours of collection





**Glove Box Preparation for
Sample Processing**

Laboratory DO Depletion Tests

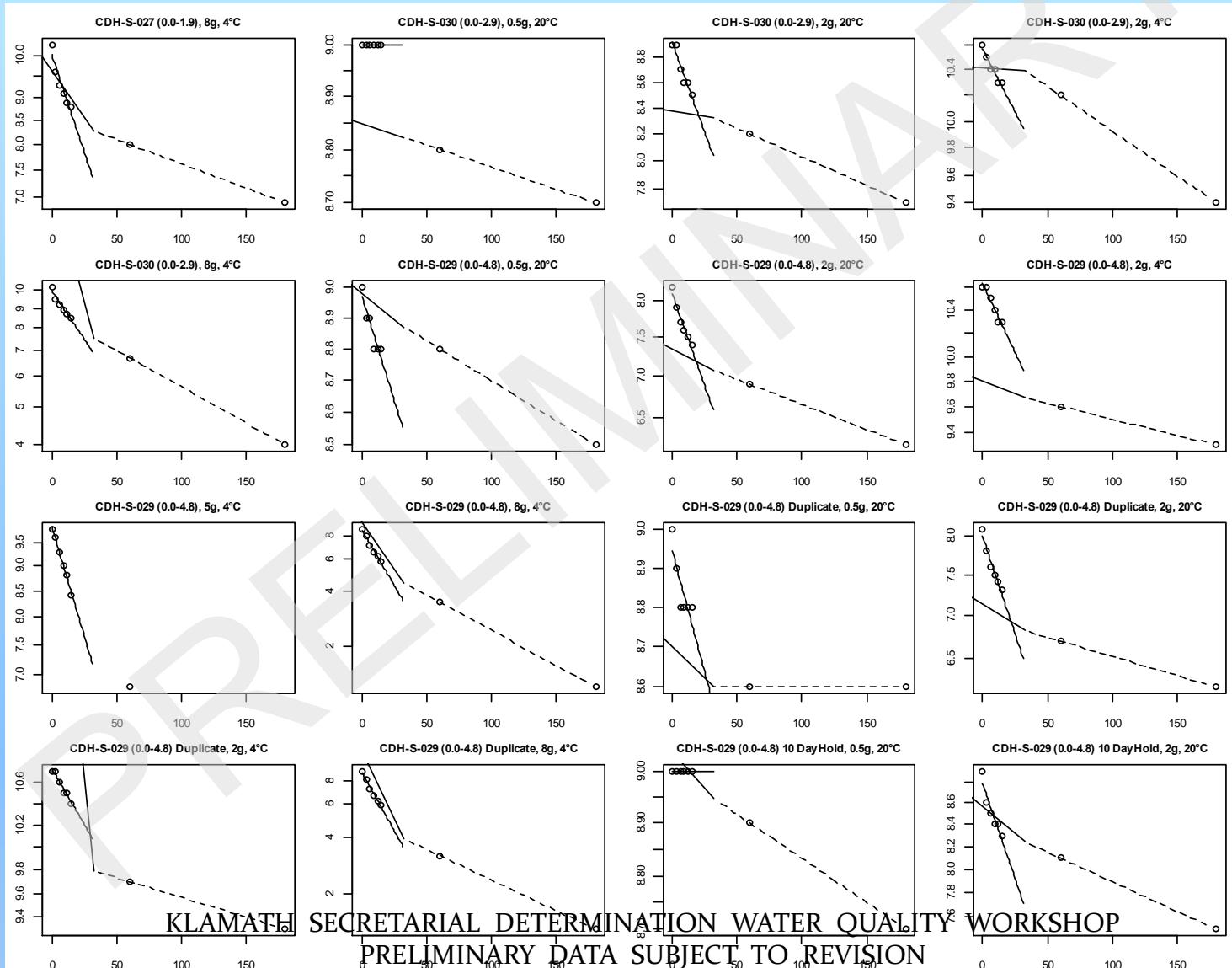
Experimental set-up in glove box



DO Depletion Analysis to Distinguish IOD and BOD

2009 Preliminary Results (t=0 to 3hrs shown)

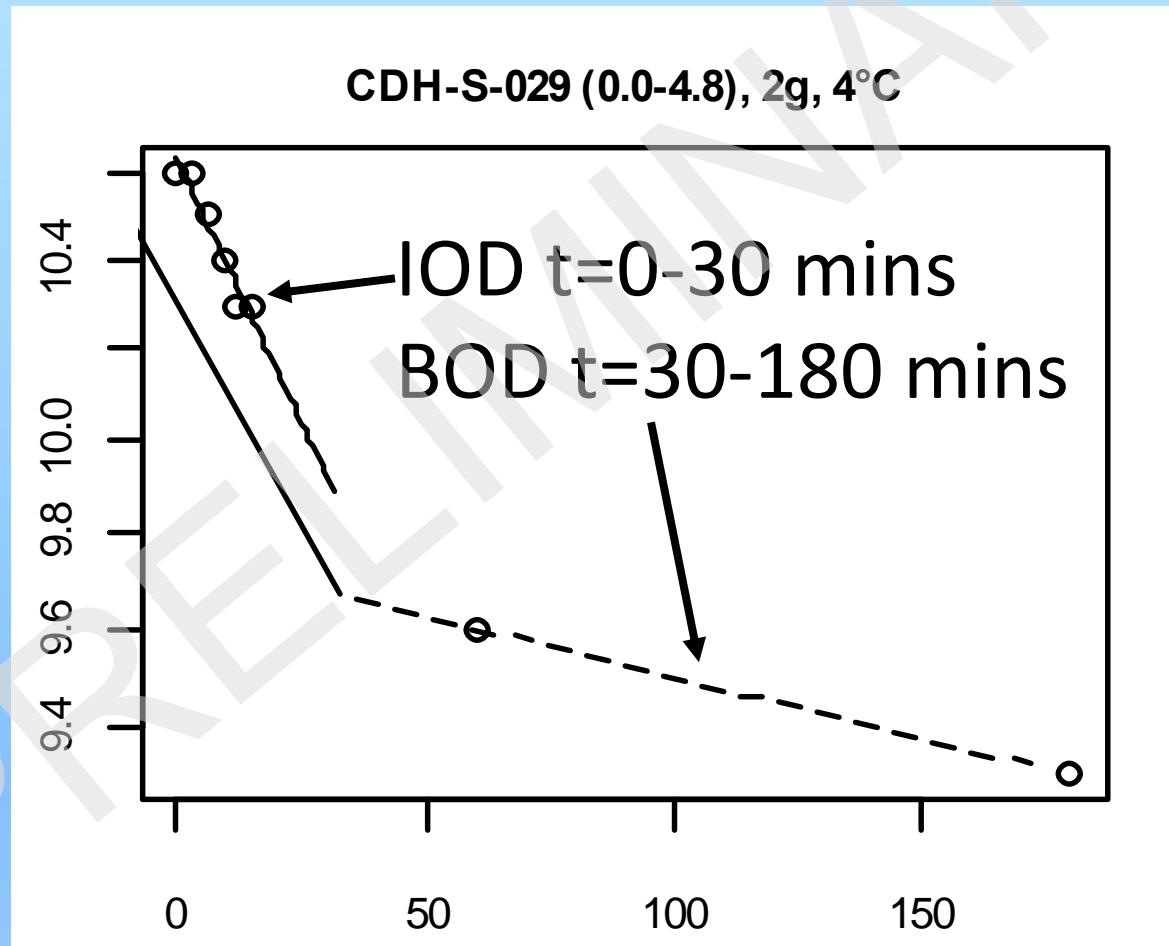
Sample mass = 0.5g, 2g, and 8g in 300 mL at 4 and 20°C



DO Depletion Analysis to Distinguish IOD and BOD

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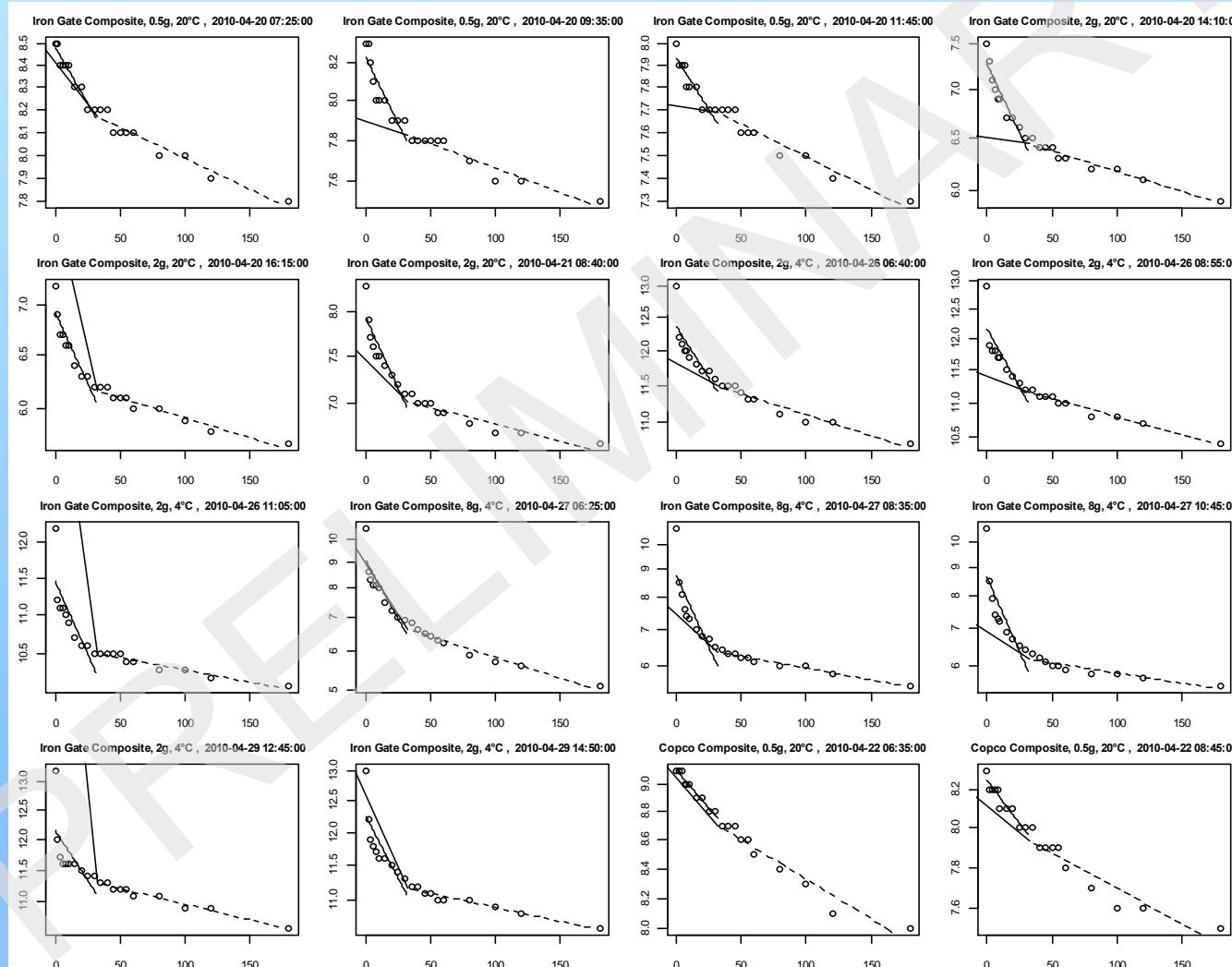
Example CDH-S-029, 2 g sample mass, 4 °C



DO Depletion Analysis to Distinguish IOD and BOD

2010 Preliminary Results (t=0 to 3hrs shown)

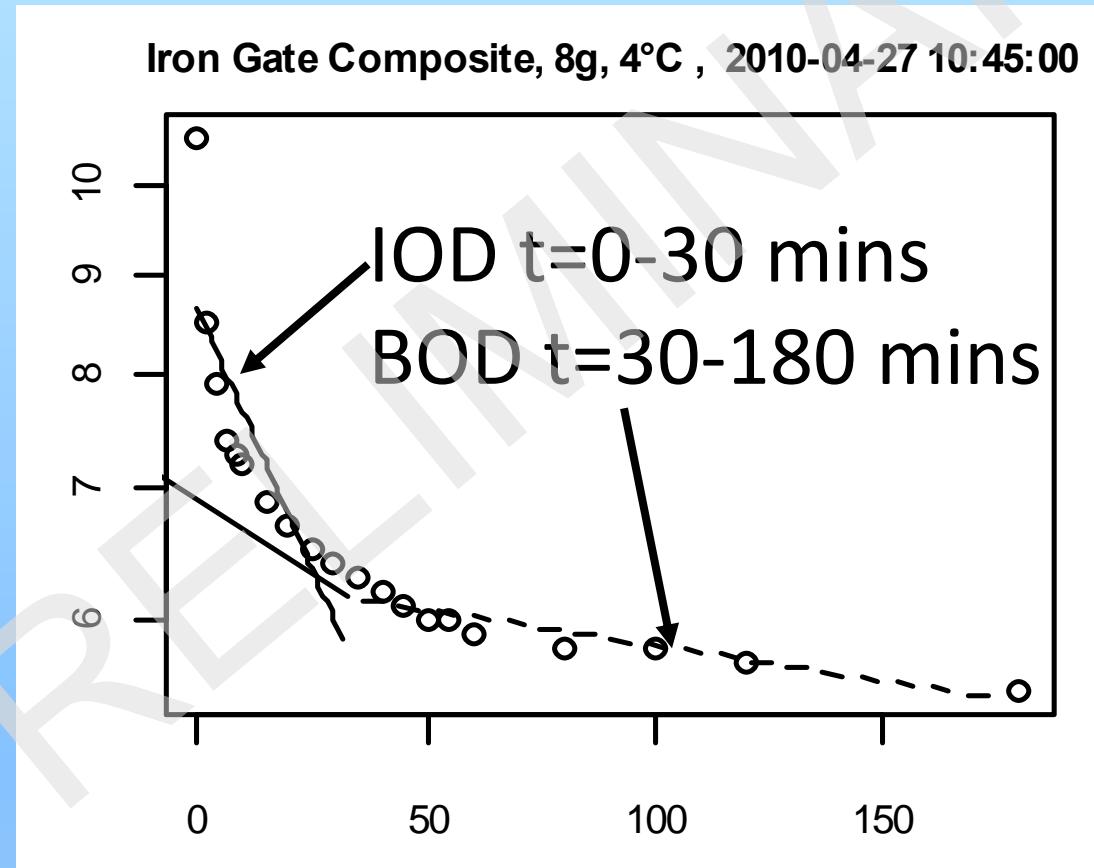
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DO Depletion Analysis to Distinguish IOD and BOD

2010 Preliminary Results (t=0 to 3hrs shown)

Example CDH-S-029, 2 g sample mass, 4 °C



IOD-BOD Spreadsheet Model* Development

- Modeling Approach
 - Represent IOD and BOD decay as separate processes
 - 1st order (exponential) approximations including downstream re-aeration and tributary dilution

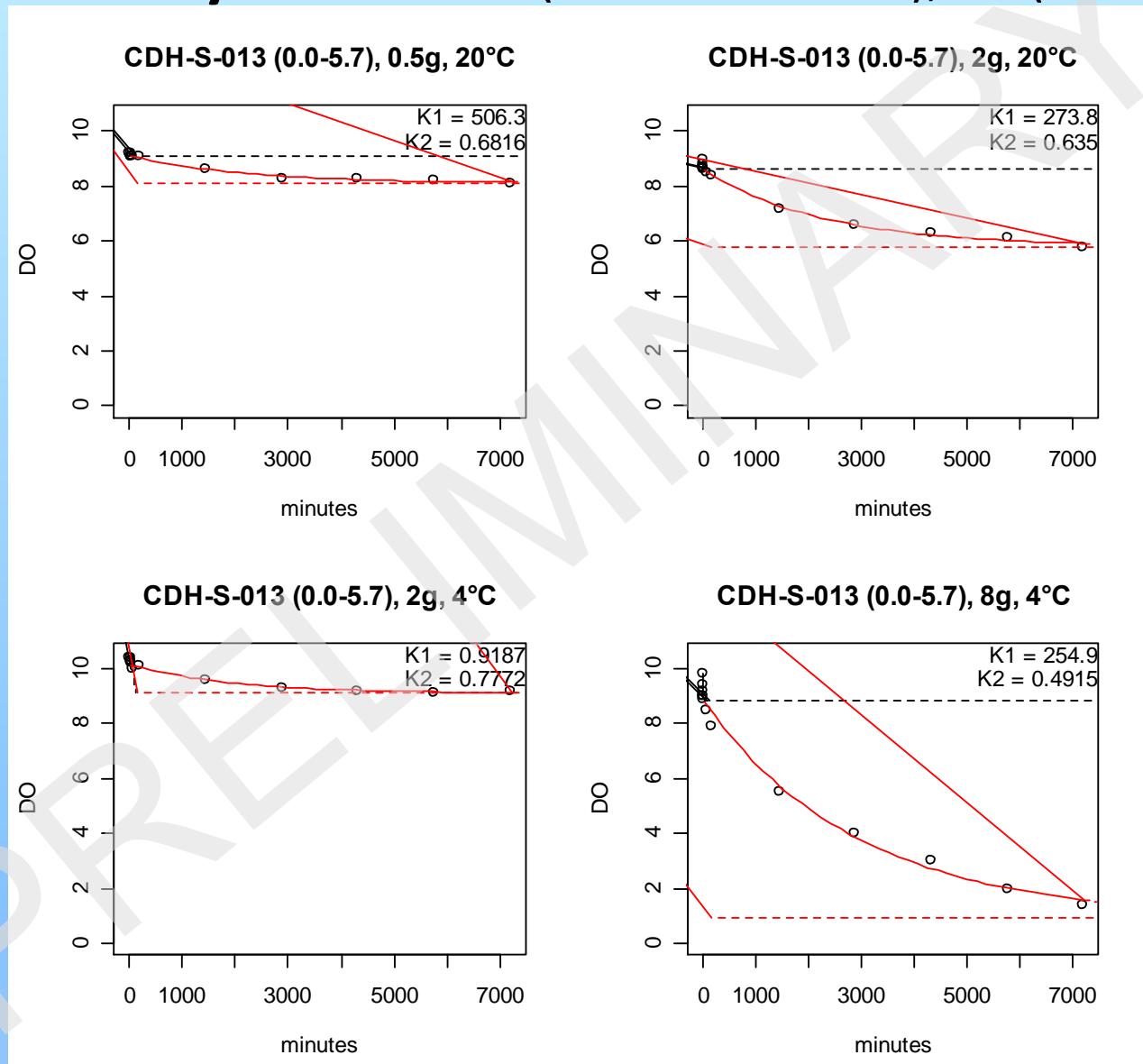
IOD-BOD Decay: $OD_{t_0}^t = OD_u(1 - e^{-K(t-t_0)})$

Arrhenius Temp Effect: $K = K_{20}\theta^{20-T}$

- Model IOD and BOD parameters (K_1 , K_2 , OD_u , Θ) based on 2009 and 2010 laboratory results
- Model TSS concentrations and flows based on 2008 sediment transport modeling results and historical flow records
- Model re-aeration coefficients based on established empirical relationships and existing data

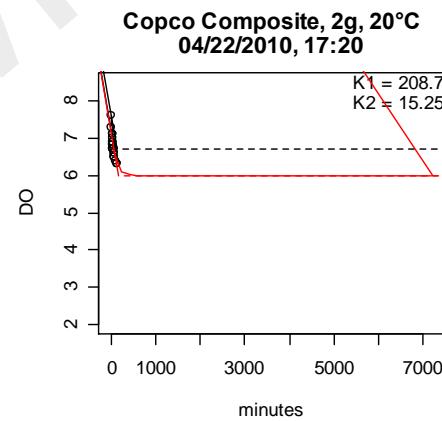
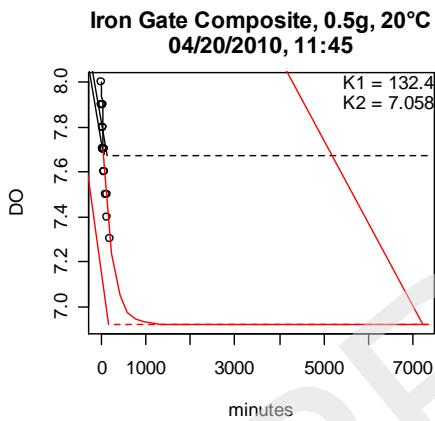
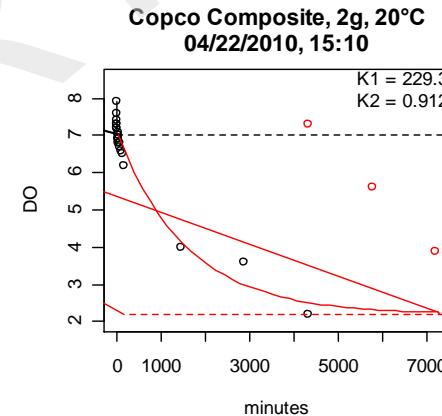
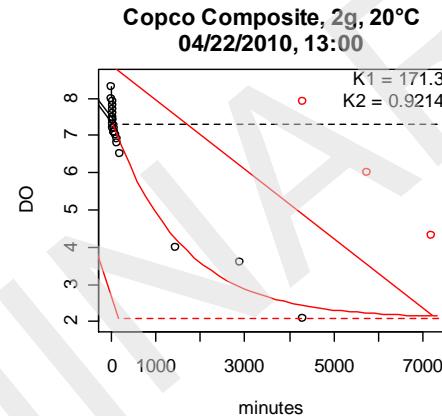
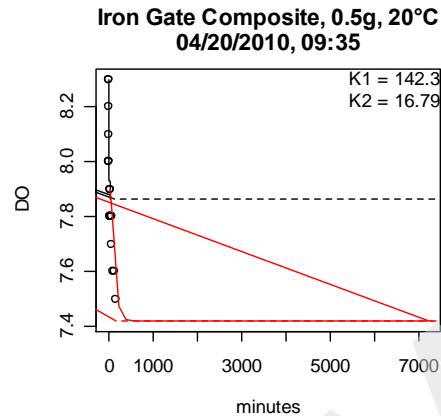
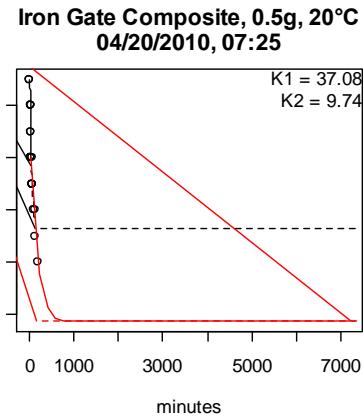
Exponential First-order Decay Fit (Example)

2009 Preliminary Results K1 (Data $t < 30$ min), K2 (Data $t > 30$ min)



Exponential First-order Decay (Example)

2010 Preliminary Results K1 (Data t< 30 min), K2 (Data t> 30 min)



Estimated BOD-IOD Model Parameters

Preliminary Results: 2010 IOD and 2009 BOD

Component	Reservoir	Year	K20 (1/d)	theta (exp(1/°C))	ODu/TSS (mg O)/(mg dry wt)	IOD-BOD for TSS=20,000 mg/L (mg O/L)
IOD	IronGate	2009	167.9	1.024	3.702×10^{-4}	7.404
		2010	353.2	1.01	6.266×10^{-4}	12.532
	Copco	2009	214.2	1.027	2.126×10^{-4}	4.252
		2010	383.5	1.01	6.353×10^{-4}	12.706
	Combined	2009	175.8	1.025	3.163×10^{-4}	6.326
		2010	368.1	1.01	6.308×10^{-4}	12.616
BOD	IronGate	2009	0.29	1.01	2.537×10^{-3}	50.74
		2010	0.9076	1.069	4.533×10^{-3}	90.66
	Copco	2009	0.4829	1.01	1.573×10^{-3}	31.46
		2010	0.918	1.057	1.848×10^{-3}	36.96
	Combined	2009	0.3322	1.01	2.174×10^{-3}	43.48
		2010	0.917	1.067	3.214×10^{-3}	64.28

Estimated BOD-IOD Model Parameters

Preliminary Results: Re-aeration Coefficients

O'Connor and Dobbins (1958)

$$k_{ah}(20) = 3.93 \frac{U^{0.5}}{H^{1.5}}$$

Churchill, Elmore and
Buckingham (1962)*

$$k_{ah}(20) = 5.026 \frac{U}{H^{1.67}}$$

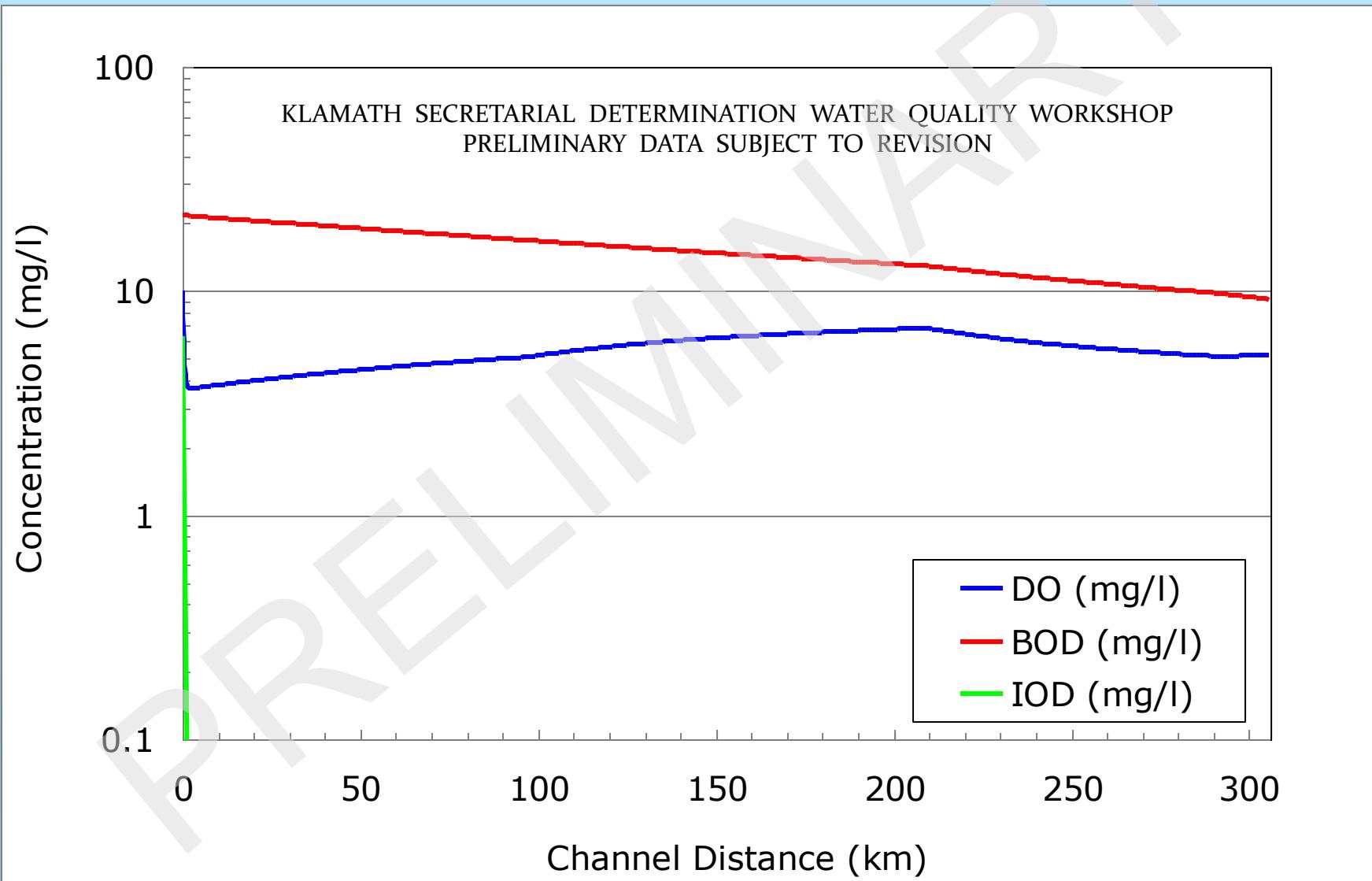
Ward and Armstrong
(2010) Klamath River *in*
situ Sonde analysis of
community respiration

$$k_a = 4.8-9.6 \text{ d}^{-1}$$

2x to 10x > O'Connor
Dobbins (1958) and
Churchill et al. (1962)

Preliminary Spreadsheet Model Results

200 m³/s, 10,000 mg/L TSS, 13°C, DO=10mg/L



Summary and Next Steps

- 2009-2010 laboratory DO depletion test results suggest rapid initial depletion of IOD (IOD K's 2 orders of magnitude > BOD K's)
 - 2010 IOD results more robust (increased resolution for $t < 3$ hrs)
 - 2009 BOD results more robust (longer test duration $t = 30$ days)
 - Variability in K values
-
- * IOD-BOD spreadsheet model refinement to better represent channel geometry
 - * Dam removal scenario refinement to better represent expected flows, TSS, and water temperatures
 - * External peer review of model parameter values
 - * Sensitivity testing of spreadsheet model

The End

